CHAPTER 4

BIOLOGICAL TREATMENT OF SOLID WASTE

Authors

Riitta Pipatti (Finland)

Joao Wagner Silva Alves (Brazil), Qingxian Gao (China), Carlos López Cabrera (Cuba), Katarina Mareckova (Slovakia), Hans Oonk (Netherlands), Elizabeth Scheehle (USA), Chhemendra Sharma (India), Alison Smith (UK), Per Svardal (Norway), and Masato Yamada (Japan)

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4.1 METHODOLOGICAL ISSUES

Composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste and sludge, is common both in developed and developing countries. Advantages of the biological treatment include: reduced volume in the waste material, stabilisation of the waste, destruction of pathogens in the waste material, and production of biogas for energy use. The end products of the biological treatment can, depending on its quality, be recycled as fertiliser and soil amendment, or be disposed in SWDS.

Anaerobic treatment is usually linked with methane (CH_4) recovery and combustion for energy, and thus the greenhouse gas emissions from the process should be reported in the Energy Sector. Anaerobic sludge treatment at wastewater treatment facilities is addressed in Chapter 6, Wastewater Treatment and Discharge, and emissions should be reported under the categories of Wastewater. However, when sludge from wastewater treatment is transferred to an anaerobic facility which is co-digesting sludge with solid municipal or other waste, any related CH_4 and nitrous oxide (N_2O) emissions should be reported under this category, biological treatment of solid waste. Where these gases are used for energy, then associated emissions should be reported in the Energy Sector.

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste material is converted into carbon dioxide (CO_2). CH_4 is formed in anaerobic sections of the compost, but it is oxidised to a large extent in the aerobic sections of the compost. The estimated CH_4 released into the atmosphere ranges from less than 1 percent to a few per cent of the initial carbon content in the material (Beck-Friis, 2001; Detzel *et al*., 2003; Arnold, 2005).

Composting can also produce emissions of N_2O. The range of the estimated emissions varies from less than 0.5 percent to 5 percent of the initial nitrogen content of the material (Petersen *et al*., 1998; Hellebrand 1998; Vesterinen, 1996; Beck-Friis, 2001; Detzel *et al*., 2003). Poorly working composts are likely to produce more both of CH_4 and N_2O (e.g., Vesterinen, 1996).

Anaerobic digestion of organic waste expedites the natural decomposition of organic material without oxygen by maintaining the temperature, moisture content and pH close to their optimum values. Generated CH_4 can be used to produce heat and/or electricity, wherefore reporting of emissions from the process is usually done in the Energy Sector. The CO_2 emissions are of biogenic origin, and should be reported only as an information item in the Energy Sector. Emissions of CH_4 from such facilities due to unintentional leakages during process disturbances or other unexpected events will generally be between 0 and 10 percent of the amount of CH_4 generated. In the absence of further information, use 5 percent as a default value for the CH_4 emissions. Where technical standards for biogas plants ensure that unintentional CH_4 emissions are flared, CH_4 emissions are likely to be close to zero. N_2O emissions from the process are assumed to be negligible, however, the data on these emissions are very scarce.

Mechanical-biological (MB) treatment of waste is becoming popular in Europe. In MB treatment, the waste material undergoes a series of mechanical and biological operations that aim to reduce the volume of the waste as well as stabilise it to reduce emissions from final disposal. The operations vary by application. Typically, the mechanical operations separate the waste material into fractions that will under go further treatment (composting, anaerobic digestion, combustion, recycling). These may include separation, shredding and crushing of the material. The biological operations include composting and anaerobic digestion. The composting can take place in heaps or in composting facilities with optimisation of the conditions of the process as well as filtering of the produced gas. The possibilities to reduce the amount of organic material to be disposed at landfills are large, 40 - 60 percent (Kaartinen, 2004). Due to the reduced amount in material, organic content and biological activity, the MB-treated waste will produce up to 95 percent less CH_4 than untreated waste when disposed in SWDS. The practical reductions have been smaller and depend on the type and duration of MB treatments in question (see e.g., Binner, 2002). CH_4 and N_2O emissions during the different phases of the MB treatment depend on the specific operations and the duration of the biological treatment.

Overall, biological treatment of waste affects the amount and composition of waste that will be deposited in SWDS. Waste stream analyses (see example in Box 2.1) are recommended methodologies for estimating the impact of the biological treatment on emissions from SWDS.

The estimation of CH_4 and N_2O emissions from biological treatment of solid waste involves following steps:

Step 1: Collect data on the amount and type of solid waste which is treated biologically. Data on composting and anaerobic treatment should be collected separately, where possible. Regional default data on composting are provided in Table 2.1 in Chapter 2, and country-specific data for some countries can be found in Annex 2A.1 of this Volume. Anaerobic digestion of solid waste can be assumed to be zero where no data are available. The default data should be used only when country-specific data are not available (see also Section 4.1.2).

Step 2: Estimate the CH_4 and N_2O emissions from biological treatment of solid waste using Equations 4.1 and 4.2. Use default or country-specific emission factors in accordance with the guidance as provided in Sections 4.1.1, 4.1.2 and 4.1.3.

Step 3: Subtract the amount of recovered gas from the amount of CH_4 generated to estimate net annual CH_4 emissions, when CH_4 emissions from anaerobic digestion are recovered.

Consistency between CH_4 and N_2O emissions from composting or anaerobic treatment of sludge and emissions from treatment of sludge reported in the Wastewater Treatment and Discharge category should be checked. Also, if emissions from anaerobic digestion are reported under Biological Treatment of Solid Waste, the inventory compilers should check that these emissions are not also included under the Energy Sector.

Relevant information on activity data collection, choice of emission factor and method used in estimating the emissions should be documented following the guidance in Section 4.6.

4.1.1 Choice of method

The CH_4 and N_2O emissions of biological treatment can be estimated using the default method given in Equations 4.1 and 4.2 shown below:

EQUATION 4.1
CH_4 EMISSIONS FROM BIOLOGICAL TREATMENT

$$CH_4\ Emissions = \sum_i \left(M_i \bullet EF_i\right) \bullet 10^{-3} - R$$

Where:

CH_4 Emissions = total CH_4 emissions in inventory year, Gg CH_4

M_i = mass of organic waste treated by biological treatment type *i*, Gg

EF = emission factor for treatment *i*, g CH_4/kg waste treated

i = composting or anaerobic digestion

R = total amount of CH_4 recovered in inventory year, Gg CH_4

When CH_4 emissions from anaerobic digestion are reported, the amount of recovered gas should be subtracted from the amount CH_4 generated. The recovered gas can be combusted in a flare or energy device. The amount of CH_4 which is recovered is expressed as R in Equation 4.1. If the recovered gas is used for energy, then also the resulting greenhouse gas emissions from the combustion of the gas should be reported under Energy Sector. The emissions from combustion of the recovered gas are however not significant, as the CO_2 emissions are of biogenic origin, and the CH_4 and N_2O emissions are very small so *good practice* in the Waste Sector does not require their estimation. However, if it is wished to estimate such emissions, the emissions from flaring should be reported under the Waste Sector. A discussion of emissions from flaring and more detailed information are given in Volume 2, Energy, Chapter 4.2. Emissions from flaring are not treated at Tier 1.

EQUATION 4.2
N_2O EMISSIONS FROM BIOLOGICAL TREATMENT

$$N_2O\ Emissions = \sum_i \left(M_i \bullet EF_i\right) \bullet 10^{-3}$$

Where:

N_2O Emissions = total N_2O emissions in inventory year, Gg N_2O

M_i = mass of organic waste treated by biological treatment type *i*, Gg

EF = emission factor for treatment *i*, g N_2O/kg waste treated

i = composting or anaerobic digestion

Three tiers for this category are summarised below.

Tier 1: Tier 1 uses the IPCC default emission factors.

Tier 2: Country-specific emission factors based on representative measurements are used for Tier 2.

Tier 3: Tier 3 methods would be based on facility or site-specific measurements (on-line or periodic).

4.1.2 Choice of activity data

Activity data on biological treatment can be based on national statistics. Data on biological treatment can be collected from municipal or regional authorities responsible for waste management, or from waste management companies. Table 2.1 in Chapter 2, Waste Generation, Composition and Management Data, gives regional default values on biological treatment. Country-specific default values for some countries can be found in Annex 2A.1 of this Volume. These data can be used as a starting point. It is *good practice* that countries use national, annually or periodically collected data, where available.

4.1.3 Choice of emission factors

4.1.3.1 TIER 1

The emissions from composting, and anaerobic digestion in biogas facilities, will depend on factors such as type of waste composted, amount and type of supporting material (such as wood chips and peat) used, temperature, moisture content and aeration during the process.

Table 4.1 gives default factors for CH_4 and N_2O emissions from biological treatment for Tier 1 method.

TABLE 4.1
DEFAULT EMISSION FACTORS FOR CH_4 AND N_2O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE

Type of biological treatment	CH_4 Emission Factors (g CH_4/kg waste treated)		N_2O Emission Factors (g N_2O/kg waste treated)		Remarks
	on a dry weight basis	on a wet weight basis	on a dry weight basis	on a wet weight basis	
Composting	10 (0.08 - 20)	4 (0.03 - 8)	0.6 (0.2 - 1.6)	0.24 (0.06 - 0.6)	Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. The emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.
Anaerobic digestion at biogas facilities	2 (0 - 20)	0.8 (0 - 8)	Assumed negligible	Assumed negligible	

Sources: Arnold, M.(2005) Personal communication; Beck-Friis (2002); Detzel *et al.* (2003); Petersen *et al.* 1998; Hellebrand 1998; Hogg, D. (2002); Vesterinen (1996).
Note: Default emission factors for CH_4 for anaerobic digestion already account for CH_4 recovery.

Emission from MB treatment can be estimated using the default values in Table 4.1 for the biological treatment. Emissions during mechanical operations can be assumed negligible.

4.1.3.2 TIER 2 AND TIER 3

In Tier 2, the emissions factors should be based on representative measurements that cover relevant biological treatment options applied in the country. In Tier 3, emission factors would be based on facility/site-specific measurements (on-line or periodic).

4.2 COMPLETENESS

Reporting on CH_4 and N_2O emissions from biological treatment, where present, will complement the reporting of emissions from SWDS and burning of waste and contribute to full coverage of all sources in the Waste Sector. This will be particularly important in countries for which biological treatment is, or is becoming, significant.

4.3 DEVELOPING A CONSISTENT TIME SERIES

As the methodological guidance for estimating and reporting of emissions from biological treatment was not included in the previous *IPCC Guidelines*, it is recommended that the whole time series is estimated using the same methodology. The activity data for earlier years may not be available in all countries. Also current data on biological treatment may not be collected on an annual basis. The methods for obtaining missing data are described in Volume 1, Chapter 5, Time Series Consistency.

The default emission factors are based on limited amount of studies. The data availability is expected to improve in coming years. It is *good practice* to use updated scientific information to improve emission factors when it becomes available. Then, the estimates for the whole times series should be recalculated accordingly.

4.4 UNCERTAINTY ASSESSMENT

The uncertainty in activity data will depend on how the data are collected. The uncertainty estimates for waste generation and the fraction of waste treated biologically can be estimated in the same manner as for MSW disposed at SWDS (see Table 3.5). The uncertainties will depend on the quality of data collection in the country.

Uncertainties in the default emission factors can be estimated using the ranges given in Table 4.1. Uncertainties in country-specific emission factors will depend on the sampling design and measurement techniques used to determine the emission factors.

4.5 QA/QC

The requirements on QA/QC addressed in Section 3. 8 in Chapter 3, Solid Waste Disposal, are also applicable for biological treatment of waste.

4.6 REPORTING AND DOCUMENTATION

It is *good practice* to document and archive all information required to produce the national greenhouse gas inventory as outlined in Section 6.11 of Chapter 6, QA/QC and Verification, in Volume 1 of these *Guidelines*. A few examples of specific documentation and reporting relevant to this category are outlined in the following paragraphs.

- The sources of activity data should be described and referenced. The information on the collection frequency and coverage (e.g., whether composting at households is included or not) should be given.
- Information on types of waste (e.g., food waste, garden and park waste) composted or treated anaerobically should be provided, if available.
- Country-specific emission factors should be justified and referenced.
- In cases where reporting of biological treatment will be split under several sectors and/or categories, the reporting should be clarified under all relevant sectors/categories, to avoid double counting or omissions.

The worksheets developed for the estimation of the greenhouse gas emissions from biological treatment are included at the end of this Volume. These worksheets include information on activity data and emission factors used to calculate the estimates.

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